

General comments

The manuscript has a clear overall structure and presents a concrete contribution by integrating tributary area theory (TAT), equivalent width, different pillar strength formulations, safety factor calculations, extraction ratio, and parametric analysis into an educational graphical user interface (GUI). The authors are also careful to clarify that the proposed tool is not intended to replace detailed geotechnical pillar design.

However, the manuscript appears to pursue three objectives simultaneously:

1. demonstrating that the software has been correctly implemented;
2. providing a tool for comparing different pillar design models; and
3. demonstrating its effectiveness as an educational tool.

The first objective requires a more rigorous verification of the implemented equations and computational procedures. The third objective is also only partially demonstrated by the current educational assessment. I believe the manuscript could be significantly strengthened by addressing these aspects more explicitly.

Specific comments

General / Language

The manuscript would benefit from a thorough English language and editorial revision. Although the overall message is generally clear, there are several grammatical issues, awkward formulations, and transitions that should be revised throughout the manuscript.

Abstract

1. Undefined variables and acronyms

Variables and acronyms should not be introduced in the abstract without being defined. For example, USBM, W_e , h , and other variables should either be defined when first introduced or, preferably, avoided in the abstract if they are not essential.

Introduction

2. Description of the methodology

The second paragraph of the Introduction would benefit from a more detailed explanation of the proposed approach. At present, the reader is introduced to the general problem, but the methodological contribution of the study is not sufficiently clear at this stage.

3. Transition between paragraphs

The third paragraph appears somewhat disconnected from the preceding paragraph. The transition between the discussion of pillar stability/design and the subsequent discussion should be improved to provide a clearer logical progression.

4. Research Question 2

RQ2 appears relatively weak in its current formulation. The authors may wish to reconsider whether it is sufficiently specific and directly connected to the scientific contribution of the manuscript.

Background and Educational Motivation

5. “Domino effect”

In the first paragraph, I suggest writing “domino effect” entirely within quotation marks, since this is a metaphorical description. Alternatively, “chain reaction” could be provided in parentheses.

6. Transition around Line 71

The discussion around Line 71 introduces a new idea rather abruptly. The manuscript moves from classification to pillar design without a sufficiently clear connection. Please improve the transition and explain why the classification of pillar failure/stability leads to the subsequent discussion of pillar design.

7. Section 2.1 title and content

The title of Section 2.1 suggests a broader discussion than what is actually provided. Relatively little is discussed regarding pillar design itself, and the discussion remains quite superficial. Either the section title should be narrowed or the discussion of pillar design should be expanded.

8. Scope and limitations of TAT

In Section 2.2, it would be useful to clarify that Tributary Area Theory is primarily a preliminary or pre-feasibility design approach based on simplifying assumptions. This could be stated explicitly in the final sentence of the first paragraph.

In this context, the authors should also briefly acknowledge more advanced numerical and analytical approaches that may be required for complex pillar-design problems, particularly when three-dimensional geometry, structural controls, stress redistribution, or complex excavation layouts are involved.

9. Figure 2 and Coates

Coates should also be cited when referring to case (c) in Figure 2.

10. Equation 5

The parameter A_p is not defined in Equation (5). Please define it explicitly.

11. Rectangular pillars

Please explain why the discussion and formulation are focused on rectangular pillars. If this is a deliberate simplification adopted for the educational tool, this should be stated explicitly and its implications discussed.

12. Section organization

Section 2.3.2 appears to describe material that would fit better either as a new Section 2.4 or as part of Section 3.1, particularly if its main purpose is to explain how the different empirical models are implemented in the software.

Software Architecture

13. Verification and documentation of implemented equations — major comment

The manuscript should provide a more rigorous verification and documentation of all empirical equations implemented in the software, particularly the NIOSH/Esterhuizen, Salamon–Munro, Sheorey, and Hoek–Brown formulations.

The manuscript presents several equations from different authors, but it is not always clear whether the equations implemented in the software correspond exactly to the original published formulations, including their constants, exponents, units, assumptions, and subsequent modifications.

This is particularly important because the entire comparison performed by the software depends on the correct implementation of these formulations. In this sense, Table 2 is essentially the technical core of the software, and it requires particularly careful documentation.

14. NIOSH/Esterhuizen formulation

For example, the equation attributed to Esterhuizen et al. (2011) appears to use a different geometric relationship from the formulation presented in the original work. Please carefully verify the implemented equation against the original reference and clearly state whether the authors have adopted the original formulation or a modified/subsequent version.

If any modification has been introduced for implementation purposes, the authors should explain and justify it explicitly.

15. Salamon–Munro formulation

A similar issue arises with the Salamon–Munro formulation. The original Salamon and Munro formulation is commonly expressed using a coefficient of approximately 7.2 for coal pillars. The manuscript uses a different coefficient. Please clarify the origin of the coefficient adopted in the software, including whether it results from a unit conversion, reformulation, or a different version of the model.

16. Sheorey formulation

The Sheorey model is also associated with formulations that explicitly account for additional effects beyond the simplified expression presented in the manuscript. The authors should clarify which version of the Sheorey model is implemented and explain why this particular formulation was selected.

17. Hoek–Brown formulation

The original 1980 Hoek–Brown formulation should not be presented as being equivalent to the generalized formulation currently used with GSI and the disturbance factor D. These developments were introduced in subsequent versions of the Hoek–Brown criterion.

In addition, the manuscript does not explain how σ_3 , the confinement term, is obtained from the W/H ratio. This makes the implementation difficult to reproduce. Please provide the complete procedure used to calculate σ_3 .

18. Computational verification

More generally, the manuscript describes reasonably well how the software works, but it does not adequately demonstrate how the software was verified to work correctly.

The manuscript indicates that the different routines are separated and that a validation module is included, but no unit tests, benchmark cases, or comparisons against independently calculated or published results are presented.

I strongly recommend adding a dedicated verification subsection or table showing, for each implemented model, at least one benchmark calculation comparing:

- the input parameters;
- the expected/published result;
- the result obtained with the proposed software; and
- the relative difference between them.

This would substantially increase confidence in the implementation.

Case Study, Results, and Educational Feedback

19. Table 6

The title “Input parameters...” is somewhat generic. Consider using a more informative title, such as “Input parameters used in the case study”.

20. Table 7 — notation

In Table 7, I suggest using σ_p for pillar stress, while S_p is commonly used for pillar strength. The notation should be revised to avoid potential confusion between applied stress and pillar strength.

Similarly, the variable We in this table should be described more explicitly as the equivalent width, or the corresponding ratio should be identified as the equivalent width-to-height ratio We/H .

21. Definition of safety factor

Around Line 355, the safety factor appears to have been defined using a different variable previously in the manuscript. Please check the notation and ensure that the definition of FS is consistent throughout the paper.

22. Computational verification before the case study

Before presenting the case study, I recommend adding a dedicated computational verification section/table using independently calculated or published results.

This is particularly important because the case study currently serves simultaneously as an illustration of the software and as indirect evidence that the implemented models are correct. These two purposes should be separated.

23. Selection of models for comparison

It would be useful if the user could select which models are included in the comparison. The different empirical formulations were developed for substantially different geological,

geomechanical, and mining environments. Therefore, automatically comparing all models under identical conditions may potentially suggest a level of equivalence or applicability that does not necessarily exist.

The software could potentially provide information regarding the intended application, rock type, input requirements, and limitations of each model, allowing users to make a more informed selection.

24. Figure 8

Figure 8 could potentially be used more effectively. For example, instead of showing only the evolution of FS, the authors could consider plotting pillar strength / pillar stress or an equivalent strength-to-demand relationship.

This could also provide an opportunity to compare the software results with historical empirical datasets or with plots commonly used in the literature to assess pillar-strength formulations.

25. Figure 8 title

The title placed directly above the graph in Figure 8 should be removed if it is redundant with the figure caption.

26. “Minimum W_e/H ”

The terminology “minimum W_e/H ” should be reconsidered. The current parametric analysis varies the pillar width using discrete increments. Therefore, the reported value is actually the first value in the discretized analysis that satisfies the specified criterion, rather than necessarily the mathematical minimum W_e/H . The authors could either:

- explicitly describe the result as the minimum value obtained from the discretized analysis; or
- implement interpolation/root-finding to determine the (W_e/H) corresponding more accurately to the target FS.

27. Definition of “critical model” — important inconsistency. The manuscript defines the “critical model” as:

“the empirical formulation that produces the lowest safety factor”

and this definition is also incorporated into the workflow. However, in Figure 7, the lowest safety factor is approximately 0.37 for the Salamon–Munro model, whereas the Bieniawski model gives approximately 1.24. Subsequently, in the discussion of Table 8, the manuscript states:

“the critical model corresponds to the Bieniawski model.”

These statements appear to refer to two different concepts. If “critical model” means the model producing the lowest FS, then Salamon–Munro would be the critical model in Figure 7. If it instead means the model requiring the largest W_e/H to reach the target FS, then Bieniawski may be the most demanding model under that particular criterion. I strongly recommend defining these concepts separately, for example:

- “minimum-FS model” for the formulation producing the lowest FS; and
- “most demanding model” for the formulation requiring the largest W_e/H to satisfy a specified target FS.

This distinction is particularly important in an educational tool because students may otherwise interpret “critical model” as having a unique meaning.

28. Target safety factor

From an educational perspective, it seems somewhat restrictive to introduce several different FS criteria in the background and subsequently implement a single fixed threshold of 1.6.

I suggest allowing the target FS to be defined by the user, or alternatively allowing the software to provide several selectable design criteria together with their corresponding references.

In addition, I recommend avoiding statements suggesting that $FS > 1$ “ensures stability.” Within the simplified framework adopted here, $FS > 1$ means that the calculated pillar strength exceeds the calculated applied stress. It does not, by itself, constitute a guarantee of operational or geotechnical stability.

29. Educational assessment

In Section 4.5, please indicate the academic program/degree of the participating students. This information is important for interpreting the educational assessment.

30. Educational effectiveness

The educational assessment should be presented as exploratory. With only $n=10$ students and a questionnaire primarily assessing perceived usefulness, the results do not directly demonstrate an improvement in conceptual understanding.

I therefore recommend reducing statements regarding the educational effectiveness of the software and explicitly stating that the current assessment primarily measures perceived usefulness and student feedback.

A future study could use a pre-test/post-test design to directly evaluate changes in conceptual understanding.

Reproducibility

31. Reproducibility — major comment

Reproducibility is currently insufficient for a manuscript whose main contribution is a computational/software tool. The manuscript explicitly states:

“the application is still under development.”

and that the code is therefore not publicly available. I understand that the authors may not yet be ready to release the complete source code. However, some level of reproducibility should still be provided. At minimum, I recommend reporting:

- Python version;
- versions of the main libraries/packages;
- operating system;
- software/executable version;
- benchmark or test dataset;

- reference input/output cases;
- computational verification procedure; and
- ideally, a GitHub or Zenodo repository.

Even if the source code remains closed, providing a benchmark dataset and a versioned executable would allow other researchers and educators to reproduce and independently check the reported results.

Applicability and limitations of the empirical models

32. Model applicability should be made explicit. The manuscript appropriately recognizes that the empirical models were developed using different databases, rock types, mining methods, and geological conditions. However, this information should be incorporated more explicitly into the software itself. For each model, the GUI could provide information such as:

- original application context;
- rock type;
- principal input parameters;
- calibration database;
- applicable geometry or aspect-ratio range, where available;
- main assumptions; and
- known limitations.

This would not only improve the technical usefulness of the tool but would also strengthen its educational value by teaching students that empirical equations should not simply be treated as interchangeable alternatives.

Novelty relative to existing software

33. The novelty relative to existing tools should be better demonstrated

The discussion of S-Pillar, CPillar, and ACPS is useful, but the research gap and the specific contribution of the proposed tool could be formulated more convincingly. The manuscript indicates that existing tools are more oriented toward specific engineering applications, whereas the proposed software focuses on education and comparative analysis. However, this distinction would be much clearer if the authors included a comparative table of existing tools. For example, the table could compare:

Feature	S-Pillar	CPillar	ACPS	Proposed tool
GUI				
Educational focus				
Multiple pillar-strength models				

TAT

Equivalent width

Parametric FS analysis

Extraction ratio

Model applicability information

Open source / reproducibility

Such a comparison would help demonstrate more clearly what is novel about the proposed software rather than simply stating that it has an educational focus.